ASSOCIATION OF THE THREESPOT DAMELSFISH (STEGASTES PLANIFRONS) IN RIDGE MORTALITY OF DIPLORIA STRIGOSA IN THE FLOWER GARDEN BANKS OF THE NATIONAL MARINE SANCTUARY

A Senior Thesis

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Association of the Threespot Damselfish (*Stegastes planifrons*) in Ridge Mortality of *Diploria strigosa* in the Flower Garden Banks National Marine Sanctuary

by

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Abstract

Association of the Threespot Damselfish (*Stegastes planifrons*) in Ridge Mortality of *Diploria strigosa* in the Flower Garden Banks National Marine Sanctuary

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Ridge mortality is a new coral malady, observed only at the Flower Gardens National Marine Sanctuary and the Florida Keys Sanctuary. Its effects are most dramatically seen on the brain coral (*Diploria strigosa*). This paper is an attempt to numerically establish, an association between the threespot damselfish, *Stegastes planifrons,* and *D. strigosa* affected by ridge mortality. It is known that *S. planifrons* farm algal patches on open spaces on or around *D. strigosa*, however it is not known whether or not they farm in higher percentages on corals with ridge mortality. The is the main question this paper addresses. In addition, tests conducted in this project also investigated *S. planifrons* specific role in ridge mortality. The question is whether the fish initiates the condition by biting coral tissue, or if they take advantage of the open space the condition has made available for farming. Sampling techniques included diver transects, photography and habitat observation. With data collected I have analyzed percent cover of ridge mortality, distribution of *S. planifrons* , and the correlation between *S. planifrons* presence and the size of the area infected with ridge mortality. The studies conducted in this research do not give conclusive answers about the cause of ridge mortality, however, they do establish a relationship between *S. planifrons* and ridge mortality.

Introduction:

The East and West Flower Gardens banks, located in the Northwest Gulf of Mexico, about 180 km south southeast of Galveston, Texas, support two of the northernmost coral reefs in the Western hemisphere. (Fig. 1 & 2). These reefs are located on the edge of the continental shelf, and rise from depths over 100 m to within 18 m of the surface (Bright, Gitttings, Hagman 93). The crests of the two banks are 19 km apart. The banks occupy an area of over 300 acres and are separated from the nearest coral reefs off Tampico, Mexico, by more than 500 kilometers (Bright, Gittings, Rezak 90). Due to this isolation, the Flower Gardens are relatively low diversity reefs. Only 21 of the 65 Western Atlantic reef building corals occur here; only 250 species of reef invertebrates, 175+ species of fishes and 80 species of marine algae are found on the Flower Gardens Banks (Gittings pers.com.). The growth of the corals that do occur here, however, is comparable to that of other more tropical reefs and percent cover exceeds that of most coral reefs.

The Flower Gardens banks lie on the crest of salt domes that formed over 130 million years ago when the Gulf of Mexico was an evaporative basin. The basin acquired large amounts of salt. These salt deposits, however, were eventually baried under terrigenous sediments. Salt is lighter then the terrigenous sediments and over time has pushed upward. This process created the salt domes, which rise from 400 feet of water to within 60 feet of the surface (Gittings, Ostrum, Deslarzes 96).

These reefs were discovered by snapper fisherman in the 1880's. They were named the Flower Gardens by the fishermen for the brightly colored pieces of coral and sponge that adhered to their fishing lines. At the time they believed the rocks below were covered with flowers. The Flower Gardens were mapped in 1937 by the U.S. Coast and Geodetic Survey (Gittings et al. 96). Since the 1970s several scientist have conducted studies on the Flower Gardens (Gittings et al. 96). Distance from land has kept the Flower

Gardens relatively pristine. In 1992 the Flower Gardens were designated a National Marine Sanctuary by the National Oceanic and Atmospheric Administration (NOAA). This designation eliminated most types of collecting in the area and prevents vessels from anchoring on the reef. In 1990, 24 volunteers placed permanent moorings on the banks to further protect the reefs from damage.

One of the most significant biological impacts on the coral reef is coral diseases. Within the last 20 years concern has developed about the health of the coral reefs worldwide. Reefs are being damaged by dredging channels, oil spills, increased temperature, sedimentation resulting from land use, and biological diseases. Some widespread diseases of reef building corals include: Black Band, White Band, Shut-Down-Reaction, Rapid Wasting Disease and Ridge Mortality (Zimmerman 95). Black band is an algal infection named for the dark mass of algae that moves across the coral, leaving bare skeleton behind it (Rutzler 83; Edmunds 91). White band also forms a line that travels along the coral, leaving bare skeleton behind it. However, the cause of white band disease has not been identified (Peters 82). Shut-down-reaction occurs under stressful conditions such as continuous sedimentation or elevated water temperatures (Antonius; Zimmerman 95). When this occurs the coral tissue sloughes off rapidly (about 10 cm per hour) until the entire colony is dead. Rapid Wasting Disease is the newest documented coral malady. It was previously thought to be caused by parrotfish bites on the coral, however it now appears there may also be some kind of disease agent involved, with the parrotfish serving as the agent of infection. This condition causes the coral skeleton to crumble and rapidly disappear (Yoon 97). These diseases have taken a toll on many coral reefs. The Flower Gardens, however, have remained unaffected by any of these diseases.

Ridge Mortality is the only disease type condition know to occur on the Flower Gardens, with the exception of mild bleaching (Hagman, Gittings 92). (Bleaching is the loss of a corals symbiotic algae due to high temperature or high stress levels. It can be widespread, however, most bleached corals recover soon after the "bleaching" event.) Ridge mortality was first noted by Abbott (1979). He described it as "ridge mortality" because, "The necrosis begins on the ridges of tissues on the surface of the colony, eventually causing the ridges to become blanched and tissueless" (Abbott 1979). As the disease progresses, it moves into the valleys and eventually kills the entire coral. Abbott further explains that, "Green colored filamentous algae colonize the ridge where the living tissue has receded. The rapidity by which the growth of these algae follows the necrosis suggest the possibility that the necrotic process is initiated by some cytotoxic agent produced by the algae. This speculation is not yet tested." Abbott has proposed that it is an algal toxin that causes ridge mortality (Abbott 79).

In 1994, Dr. Debby Santavy of the EPA in Gulf Breeze, Florida, first proposed that damselfish may actually be responsible for ridge mortality. Subsequent field observations confirm that in many cases damselfish are inhabiting corals with ridge mortality (Gittings, pers. comm.).

Damselfishes are deep bodied, compressed and range from 75 to 150 mm in length . They are well adapter for life on the coral reef. A number of damselfishes are herbivorous and occupy territories on reefs. Some species of territorial damselfishes are extremely aggressive, even attacking a diver who refuses to leave their territory (Robertson 84). A damselfishes territory often includes an algal patch, which the fish grazes and patrols. There are six species of damselfish found on the Flower Gardens Banks. They are the Threespot Damselfish (*Stegastes planifrons*), Cocoa Damselfish (*S. variabilis*), Longfin Damselfish (*S. diencaeus*), Dusky Damselfish (*S. fuscus*), Bicolor Damselfish (*S. partitus*) and Yellowtail Damselfish (*Microspathodon chrysurus*). (Humann 93)*Stegastes planifrons* is by far the most common damselfish on the Flower Gardens (Fig. 3). It is also the most aggressive and easiest to identify in the field. For these reasons, I focused my study on the Threespot Damselfish.

The association of damselfish with ridge mortality has never been studied. If damselfish actually cause the ridge mortality condition, it could mean that they are biting and possibly eating the brain coral surface in order to create a new bare area for algal patch growth. Though present on most affected corals, it is also possible that damselfish do not cause the condition. That is, the damselfishes may be opportunist, and take advantage of the bare space left behind by the ridge mortality. They may simply use this new open space to farm their algal patches. My goal is to test the hypothesis that damselfishes are associated with ridge mortality, and possibly to investigate the role of the threespot damselfish in the spread of the malady. My study will concentrate on the most common brain coral on the Flower Gardens, *Diploria strigosa*, (Fig. 4) and the threespot damselfish.

Materials and Methods:

Data for this project was collected from June 1997 through March 1998. I visited the Flower Gardens two times last summer and three times throughout the school year. Most collecting trips lasted two to five days and three to five scuba dives were made daily. Each dive was dedicated to running a transect, taking photographs or observations of ridge mortality and threespot damselfish. (Fig. 5) Much of the data for this project was collected by divers. One of the main sources of information was transects. One dive encompassed one transect. Each transect followed a random compass heading. Compass headings for each transect were not set until the diver reached the bottom. This was done so that the researcher could begin his dive against the current and then on the second half of the dive when he was tired, the researcher could drift back to the boat in the current. Precaution was taken not to follow the same degree readings on the same buoys. Each transect was designed as a straight line out and back in. Data was collected along the transect line and within two meters of either side of the transect line. Distance on each transect was not recorded, as it deemed valuable in the original design of this project. Length therefore, depended on the research diver's air supply. On each transect the following information was recorded:

- Number of *D. strigosa*,
- Number of *D. strigosa* infected with ridge mortality,
- Size of each coral colony,
- Size of each infected area,
- Frequency of infected areas on each colony,
- Presence or absence of damselfish on each diseased colony
- Presence or absence of damselfish on healthy colonies

Each transect surveyed between 50 - 200 corals. I attempted to swim three to five transects at each site. I was not always able to accomplish this due the boat schedule. With data on the number of corals with the condition and the number of affected areas on each coral I generated a variance to mean ratio for each transect.

I analyzed the distribution of ridge mortality among affected colonies and determined whether it occurs randomly, regularly, or clumped distribution. Data was also analyzed by site (i.e. mooring buoy location). When I had collected transects from several mooring buoy locations I created frequency of occurrence graphs.

Transect data was compiled and analyzed with Excel. Once spreadsheets were made the data was scanned and reorganized to find any patterns. Graphs were compiled to show:

- Percent occurrence of ridge mortality
- Number of infected areas per colony
- Damselfish presence on corals with ridge mortality
- Damselfish presence on corals without ridge mortality
- Distribution of damselfish
- Damselfish association with ridge mortality as number of infected spots per coral increased

- Damselfish association with ridge mortality as size of largest infected spot per coral increased
- Damselfish association with ridge mortality as total area of infection per coral increased

I spent several dives observing damselfish behavior on healthy and on diseased corals. On these dives I documented the size of the damselfishes territory, any biting behavior of the damselfish, how many algal patches each fish guarded, and how often the fish moved off its algal patch. Observation also included video. On several dives I recorded video of infected corals and the damselfish present on them. This way I was able to document my sightings and review them again later.

I took several still frames photographs of entire diseased colonies. I also took close-up shots of the infected areas. With large frames I was able to look for patterns and general characteristics of the ridge mortality condition. Close-ups were used to observe the coral septa. Each coral polyp is made of a calcium carbonate skeleton. On the ridge of the skeleton are tiny projections called septa (Fig 6). These projections are very fragile. Closeup photographs reveal the condition of these septa.

One question I wanted to answer was how fast damselfish would inhabit a new open area. The best way to do this would be to actually create a new open area on a coral by scraping off the living tissue of an existing coral. However, this is illegal in the sanctuary, so the next best option was to place already dead pieces of coral underwater. Three pieces of dead brain coral (each approx. 12 square centimeters) were laid in several locations for up to two days. Each was observed every few hours for any sign of damselfish activity.

One final project was to collect a sample of the algae found on the corals infected with ridge mortality. The samples were then sent in to Texas A&M at Corpus Christi for identification. The results were then researched to find the role of these species in the reef environment and if they were commonly observed in *S. planifrons* habitat.

Results:

Diploria strigosa:

Data collected along the 26 transects run in this study revealed that 10.2% of *D. strigosa* had evidence of ridge mortality. The incidence of ridge mortality along transects ranged from 0-40%. Forty two percent of corals with ridge mortality had only one infected area. When divided into corals without damselfish and corals with damselfish, the numbers were nearly the same, with 43% of the corals without damselfish showing only one infected area (Fig. 7) and 42% of corals with observed damselfish having one infected area (Fig. 8). The distribution of ridge mortality on each individual coral therefore, can be clumped or random.

It took several dives before any pictures of the quality I needed turned out. However, I was able to gather several good pictures of corals with ridge mortality. When I examined pictures of entire colonies with the malady I found two different, distinct patterns. One pattern of ridge mortality consisted of long, continuous lines of bleached or dead tissue along the ridges (Fig. 9). Often several ridges next to each other would be infected. The other pattern consisted of small, circular areas of tissue death along the ridge (Fig. 10). Several of these circular patterns would be on surrounding ridges also, however, they were often not continuous lines like the first pattern.

When I examined the septa of the infected areas I found ridges on early stages or on the perimeter of advanced stages of ridge mortality were intact. However, septa on the interior of advanced cases of ridge mortality were often broken.

The algal samples sent to the laboratory were small and therefore it was hard to key to species. However, most were identified to genus. The algae in the samples consisted of:

- *Polysiphonia sp.*
- *Bangia sp.*

- *Erythrotrichia sp.*
- *Derbesia sp.*

Stegastes planifrons:

Damselfish numbers varied greatly on the transects, ranging from zero to twenty five individuals. Most *S. planifrons* observed were living on or near a brain coral. None were seen swimming in the water column. Most *S. planifrons* were farming an algal patch.

General observation revealed that *S. planifrons* did not always remain on their algal patch. They often had a hiding place they would swim to when the diver approached. The hiding area was usually near the patch. When I remained stationary, the *S. planifrons* usually returned to their patch. However, they rarely remained there the entire time. It was common for the *S. planifrons* to swim to a nearby coral head or under a nearby ledge, usually returning to his algal patch within a minute. Observation times were 5-10 minutes. *S. planifrons* were never observed biting healthy coral although they were often observed biting their algal patch.

Association:

Of 2,045 *D. strigosa* sampled 205 showed signs of ridge mortality. *S. planifrons* inhabited 86 of these 205 corals. This means the fish were present on 58.04% of these infected corals. Of the 1,840 healthy brain corals, only 261 had a resident *S. planifrons.* This translates to 14.18% inhabitance (Fig. 11).

I plotted *S. planifrons* presence and absence verses size of the ridge mortality. Size of the infection was measured in three ways:

- Number of infected spots (Fig. 12)
- Largest infected spot (Fig. 13)
- Total area of all infected spots (Fig. 14)

No matter how size was measured, the graphed results were all similar. At smaller sizes, damselfish were present nearly half the time. However, as disease areas increased in size or number, damselfish presence rose dramatically.

When dead pieces of coral were place on the reef to measure how quickly the damselfish would inhabit a new open space, no damselfish activity was observed. Each coral was left out from one to two days but no damselfish inhabited them.

Discussion:

Diploria strigosa:

D. strigosa is one of the most common hermatypic (reef building) corals worldwide. It covers 7.% of the East Flower Gardens Banks and nearly 10% of the West Flower Gardens Bank (Gittings et al. 92) This makes it the second most abundant coral on both Flower Gardens Banks (*Montastrea anularis* being most abundant). Disease and pollution do not seem to curbing *D. strigosa's* growth. For every square meter of live tissue lost, studies show 1.5 square meters of live tissue are replacing it (Gittings et al. 92). The corals strength is shown again in studies where several coral species were subjected to sedimentation (Rogers 83), oil and oil dispersants (Dodge et al. 84, Knap 87; Cook 83). In all test *D. strigosa* recovered better than all other corals tested. Of all reef building corals *D. strigosa* is probably the most successful and hardiest species.

However, we still find that 10.2% of the Flower Garden's *D. strigosa* are infected with ridge mortality. Before my study no statistic was available on ridge mortality's percent cover of *D. strigosa*. It is believed, however, that the frequency of ridge mortality on all corals of the Flower Gardens is somewhere between 2% - 5% (Gittings 1992). Percent cover is a very important statistic in a study such as this. This number allows us to know in the future if the malady is spreading, stabilizing or decreasing. The number I recorded is therefore a baseline number for further studies.

The fact that 42% of corals with ridge mortality had only one infected area did not give any evidence that ridge mortality was randomly distributed or clumped. It appears the infection can have either distribution. This does not give us information about *S. planifrons* association with ridge mortality. However, it will be a helpful defining characteristic in future studies of the condition.

According to a Robertson et al. (81), damselfish defend fairly small areas. Damselfish also often have territories that are adjacent to each other and sometimes even overlap (Robertson et al. 1981). Damselfish territories are about 2.5 times larger than their algal mat. All these facts lead me to believe it is possible for several damselfish to farm on one large coralhead. Therefore, even if the fish were causing the infection, there could still be more than one spot on the coral. Because of this, relating the presence of several spots on a coral to a disease condition can be misleading. Several infected spots on a coral could just as easily be due to several damselfish farming on the same coral.

Photography revealed two different patterns of ridge mortality. This presents the possibility that there are actually two strain of this condition. These patterns are so distinct and different that it may give evidence of two different causal agents. Close-up photography revealed the structure of the skeletal septa on the corals. This showed there was much septa destruction on advanced cases of ridge mortality. Most of the damage was in the central area of the infection. This is not surprising. Damselfish are known to eat the algae in their patches. As they bit at the algae it is probable that they also break off bits of the coral septa. However, we cannot disregaurd the possibility that it could also be a disease agent that could cause the coral skeleton to crumble (as in Rapid Wasting Disease). It is interesting that septa were not damaged on newly infected areas or on the perimeter of advanced areas. If *S. planifrons* biting was destroying septa in the larger infected areas, it seems they are not biting new or perimeter areas. These smaller areas often do not have a full mat of algae for the *S. planifrons* to graze upon. It would make sense that if the *S. planifrons* were eating the algae, they would not bite new or perimeter areas. However, if they caused the condition by biting the corals, there should also be destruction on these stages of the infection. This makes it clear that the *S. planifrons* are using the open area on infected corals in large infected areas, but leaves their use of new and parameter areas questionable.

Stegastes planifrons:

S. planifrons is the most common damselfish at the Flower Gardens (Pattengill pers. com.) It is also one of the most fiercely territorial of the damselfishes (Thresher 70; Williams 79). I was originally under the impression that it was not normal *S. planifrons* behavior to bite the coral tissue in order to create or increase their algal mat (Potts 77). However, two articles stated that damselfish actually do bite coral in order to increase the size of their algal patches (Bythell 93; Robertson 81). Neither article stated that damselfish would bite coral to create a new patch. When damselfish stomach contents were analyzed, their diets were found mainly to consist of diatoms, green algae and small crustaceans (Robertson 81). Coral tissue was not detected. This means that damselfish do not commonly eat coral. Biting is probably rare.

To be sure that damselfish were not biting corals I set up several stations near infected corals with a resident damselfish and observed them for three to five minutes. As stated earlier, no damselfish bites on live coral tissue were ever observed. This is important to note. Without biting the coral tissue it would be unlikely that the damselfish were causing the damage known as ridge mortality.

When observing stations, I also took note of the damselfishes positions. I found that damselfish did not always remain on their algal patches. They would often leave and swim to a nearby coralhead for times usually less than a minute. This information could explain the fact that damselfish were not seen on all large infected coralheads. It is possible that when the observer approached while swimming the transect, a resident damselfish may have been currently off the patch. However, the patch could still have had a resident damselfish.

The threespot damselfish population at the Flower Gardens is much higher than the average. According to Christy Pattengill, a graduate student conducting fish surveys at the Flower Gardens, *S. planifrons* were sighted on 94-97% of roving dives. In comparison, in the Florida Keys *S. planifrons* were only sighted 37-82% of the time. I theorized that this high population of damselfish could be an explanation for the damselfish biting the corals to create open area. However, several studies have been done on damselfish populations in Panama and the Florida Keys. These studies found that damselfish populations were not near there carrying capacity. (Robertson 1981) In these studies half the reef was removed and, it was found that damselfish density doubled on the remaining half. The population did not decrease.

This study shows that damselfish populations at the Flower Gardens are probably not at their carrying capacity. The high population at the Flower Gardens is possibly due to the fact that the Flower Garden's reefs begin at a much greater depth than most tropical reefs. Studies have shown that damselfish naturally occur in higher numbers in deeper habitat (Fortin et al. 95). The highest numbers were in depths around sixty feet. Most tropical reefs range from fifteen to forty feet. The Flower Gardens falls mainly in the sixty to seventy foot range.

When I observed the algal mats growing in infected areas, I found that it was common to see algae growing through the center of the coral skeleton, protruding from the mouth area. After seeing this, I hypothesized that ridge mortality may actually be cause by an algal toxin. This theory has been presented before by Dr. Rob Abbott (79). I also proposed the idea that the lethal algae may be an endolithic algae. Endolithic algae is a layer of algae that grows on the coral skeleton directly below the live coral tissue. This algae is not normally visible unless one removes the live coral tissue. However, I proposed that it is possible that less then adequate conditions could weaken a corals resistance to the growth of the algae. This could cause an algal explosion which in turn would kill the coral.

The fact that most algal samples were only identifiable to genus was due to a small sample size. Only *Polysiphonia sp.* was found on algal mats in other studies (De Ruyter Van Steveninck 84). Since it has been shown that algal mats differ greatly in composition in different areas, it may be of little value (Hixon 96; De Ruyter Van Steveninck 84). I looked up each algal genera in *Marine Plants of the Caribbean* and *Marine Algae*. All the genera were filamentous or unicellular. None of the species were specifically stated to be endolithic, however, many algal species can perform this role and also live independently. For this reason the fact that these genera were not listed as endolithic does not mean they cannot function in this manner. *Bangia* and *Erythrotrichia* of the family *Bangioideae* both had large basal holdfast which often penetrated the substrate they grew on (Taylor 60). The present evidence given from the algal samples is vague and incomplete but, the possibility that algae could be involved is a topic that needs further research.

Association:

The data showed that there was definitely a pattern of *S. planifrons* present on the infected corals. 58% of infected corals had *S. planifrons* present compared to 14% of healthy corals. These numbers cast doubt on the idea that *S. planifrons* are initiating ridge mortality. Although 58% presence shows a correlation, the percentage should be higher if the fish were the initiator. In fact, *S. planifrons* should be present on almost 100% of infected corals. The only corals observed without *S. planifrons* should be considered diver error. Only 58% presence should not be considered only diver error. It would make sense if the fish were seen on corals with ridge mortality at this high percentage because they used the open area the infection was creating. However, many small, infected corals had not yet been noticed by a *S. planifrons* and therefore had no resident.

If *S. planifrons* actually causes ridge mortality, they should be found on every affected coral. If however, ridge mortality is a disease and *S. planifrons* are merely opportunists, I should find that, although *S. planifrons* are present on larger, more progressive cases of ridge mortality, they will not be present on small, newly developed patches of ridge mortality. If we graph the latter case, with percent occurrence of damselfish verse affected patch size, almost no *S. planifrons should be* on patches of ridge mortality until they reach a certain size (Fig. 15 graph 1). At this point the graph should turn upward dramatically until the percent occurrence nears 100%. If *S. planifrons* do cause the condition, the graph of percent occurrence should begin around 100% and hold steady at this number (Fig. 15 graph 2).

As stated earlier the size of the infected area on *Diploria strigosa* was measured using three different methods: 1) number of spots, 2) size of largest spot, and 3) total area of spots. Patterns from these data were difficult to detect. This is probably due to the small size of the data set. However, the weak pattern that was visible was the same for all three methods of measurement. It showed that at early stages of ridge mortality *S. planifrons* were present around 50% of the time. However, as the infection became more advanced, *S. planifrons* presence increased and infected corals without *S. planifrons* became less common. The increase in *S. planifrons* presence shows that as the infection became more advanced, it also became more visible and the fish were able to take advantage of the open area. These data show clearly that *S. planifrons* use larger areas of ridge mortality infection to farm algae. *S. planifrons* use or disuse of small, newly infected areas is still questionable.

One set of data that at first did not seem to support the idea that *S. planifrons* take advantage of open territory was the experiment where dead pieces of coral were laid on the reef for up to two days. No *S. planifrons* activity was ever seen on these corals. The data may not be as contradictory as it first seems. Due to the regulations of the Flower Gardens National Marine Sanctuary I had to use dead coral, usually used for decoration. These dead corals are no longer part of the natural environment. They have been bleached and set in the sun in order to remove any discoloring. In other words, they are a sterile environment. When a coral dies on the reef, leaving on open space, it is far from sterile. These dead areas are inhabited by algae and hundreds of bacteria and small crustaceans. Because of this, once a damselfish begins to guard this area, it has an immediate food source, and the open space will flourish into a full-grown algal lawn fairly quickly. If *S. planifrons* inhabits a piece of dead decorative coral, it is guarding a sterile environment. This environment will not provide its host with food. Eventually the coral will be seeded and algae, bacteria and crustaceans will begin to inhabit it. However, this process takes much longer than two days and until this process begins the factors that would attract a damselfish to this spot are absent.

Conclusion:

This project has shown that *S. planifrons* are definitely associated with ridge mortality. To numerically establish this association is an important step to finding the cause and cure for ridge mortality. The tests conducted in this project are not conclusive evidence that *S. planifrons* do or do not cause ridge mortality.

Some of the tests give indirect evidence that *S. planifrons* may be opportunist rather than initiators. However, a conclusive answer to what causes ridge mortality would take years of study. Histology will be required to look for microbial inhabitants. An in depth study of the algal species present in infected areas could be very revealing. More in depth transects and *S. planifrons* behavior analysis will be required. Future transects should have a specific length and include a detailed observation of the distribution of ridge mortality on *D. strigosa* along a line. An exact percent cover of the infection on individual coral colonies will also be helpful. An extended period of time will be required to look for spatial and seasonal patterns. With these additions a larger, more detailed pool of data can be created. With this data, patterns and behaviors may become more obvious.

Thus study could provide a firm foundation for further studies. Through this study, more is known about ridge mortality then before. I have gathered some baseline data on ridge mortality. For example, the calculation of present percent cover of ridge mortality will be a valuable baseline number in the future. Without this information researchers would not know if ridge mortality was spreading or receding.

Perhaps the most important contribution of this project was the established numeric correlation between ridge mortality and *S. planifrons* . Although we do not yet understand the mechanism, we know the two are connected. Previously this connection was just an observation made by some researches. The correlation now lets future researches know that *S. planifrons* cannot be ignored when ridge mortality is studied.

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Figure Captions

Figure 1. Map showing location of topographical features in the northwestern Gulf of Mexico.

Figure 2. East and West Flower Gardens banks with sanctuary boundaries included.

Figure 3. *S. planifrons* displaying adult and juvenile color patterns.

Figure 4. Healthy colony is *D. strigosa.*

Figure 5. Sampling methods employed in the study.

Figure 6. Close up view of a coral polyp.

Figure 7. Number of infected areas per coral; damselfish present. 1= one infected area 2= two infected areas ... M= more than 12 infected areas.

Figure 8. Number of infected areas per coral; damselfish absent. 1=one infected area 2= two infected areas ... M= more than 12 infected areas.

Figure 9. First pattern of ridge mortality.

Figure 10. Second pattern of ridge mortality.

Figure 11. Association of damselfish with coral; infected and non-infected. DA= damselfish absent, DP= damselfish present, RA= ridge mortality absent, RP= ridge mortality present.

Figure 12. Damselfish presence vs. number of infected spots.

Figure 13. Damselfish presence vs. largest spot.

Figure 14. Damselfish presence vs. total area.

Figure 15. Theoretical damselfish presence with increasing infection size. Graph 1= theoretical graph if damselfish are opportunistic but not causal. Graph 2= theoretical graph if damselfish cause ridge mortality or are not associated with it at all.

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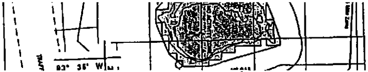


Figure 1

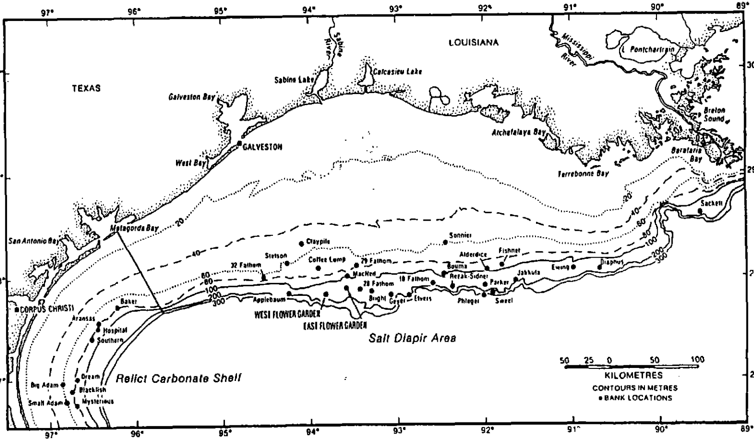


FIG. 2. Map showing locations of topographic features examined during this study.

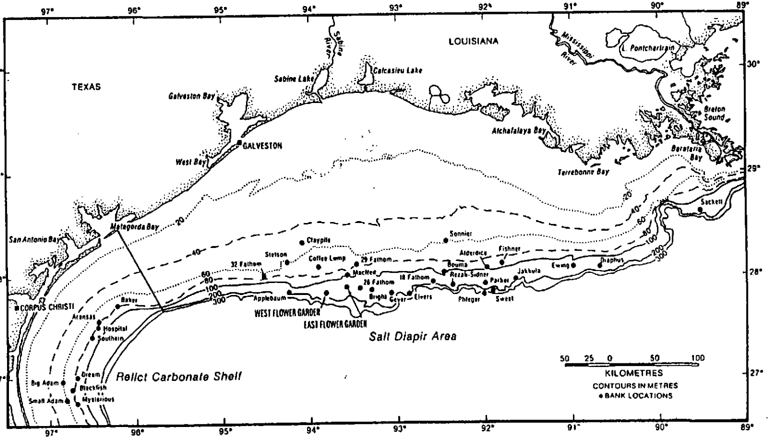


FIG. 2. Map showing locations of topographic features examined during this study.

Figure 2

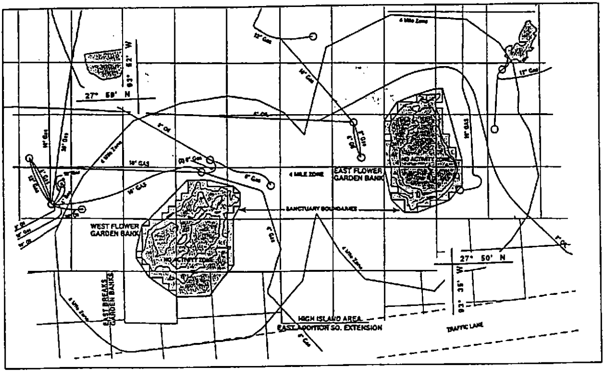
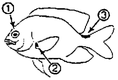

27° 59' N
93° 52' W
4 Mile Zone
EAST FLOWER
GARDEN BANK
NO ACTIVITY ZONE
4 MILE ZONE
SANCTUARY BOUNDARIES
WEST FLOWER
GARDEN BANK
NO ACTIVITY ZONE
27° 50' N
93° 35' W
EAST BREAKS
GARDEN BANKS
HIGH ISLAND AREA
EAST ADDITION SO. EXTENSION
TRAFFIC LANE

Figure 3

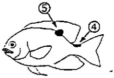
THREESPOT DAMSELFISH
Stegastes planifrons
FAMILY:
Damselfish -
Pomacentridae



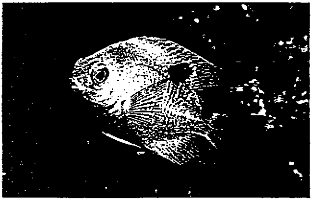
SIZE:
DEPTH: 0-130 ft.

ROATAN

Threespot Damselfish Juvenile [right]



Young Adult [far left]
Intermediate Juvenile/Adult [left]



CATMAN

Figure 4

SYMMETRICAL BRAIN CORAL

Diplora strigosa

SUBORDER: Faviida

FAMILY: Faviidae

SIZE: Colony 6 in. - 6 ft.

DEPTH: 3 - 130 ft.

Hemispherical Head Variety

Structural Detail: Note Evenly Rounded Ridges

[far left]

Encrusting Plate Variety

[near left]

Figure 5

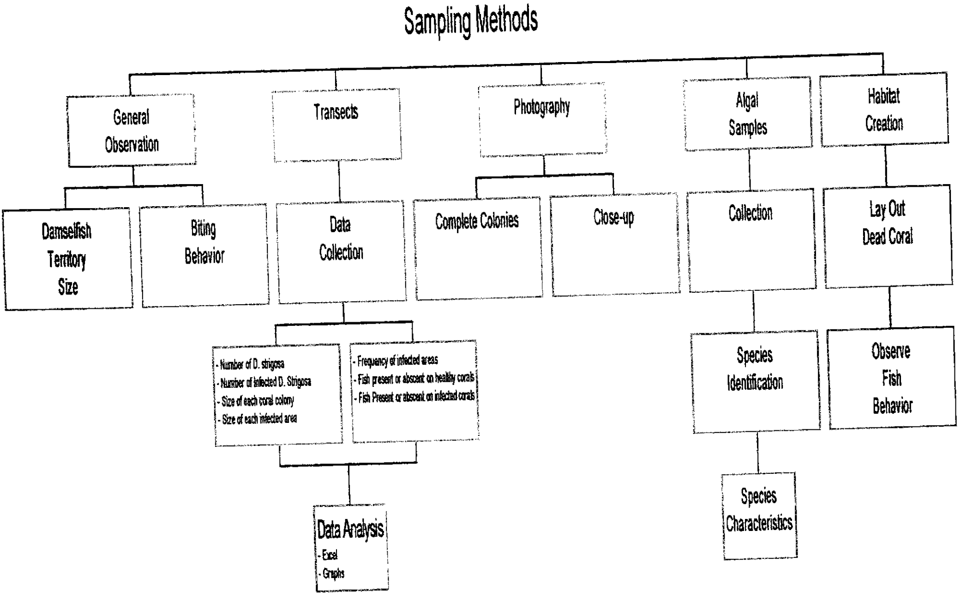
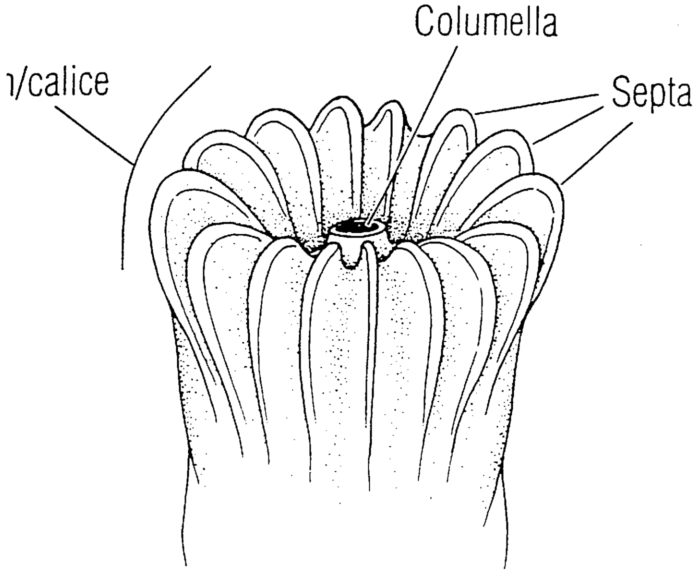

Sampling Methods
General Observation
Transects
Photography
Algal Samples
Habitat Creation
Damselfish Territory Size
Biting Behavior
Data Collection
Complete Colonies
Close-up
Collection
Lay Out Dead Coral
- Number of D. strigosa
- Number of infected D. Strigosa
- Size of each coral colony
- Size of each infected area
- Frequency of infected areas
- Fish present or abscent on healthy corals
- Fish Present or abscent on infected corals
Species Identification
Observe Fish Behavior
Data Analysis
- Excel
- Graphs
Species Characteristics

Figure 6



CORALLITE

Figure 7

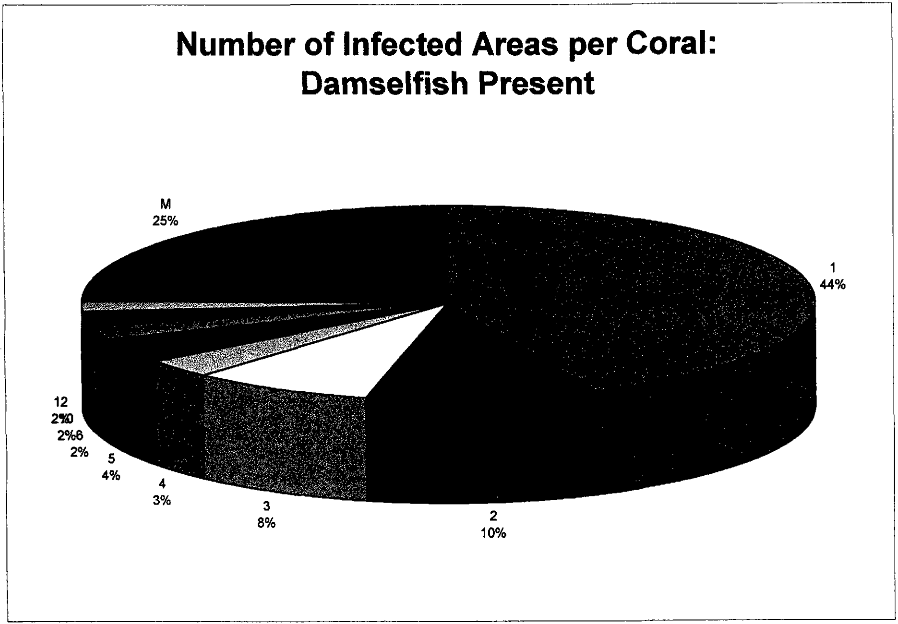
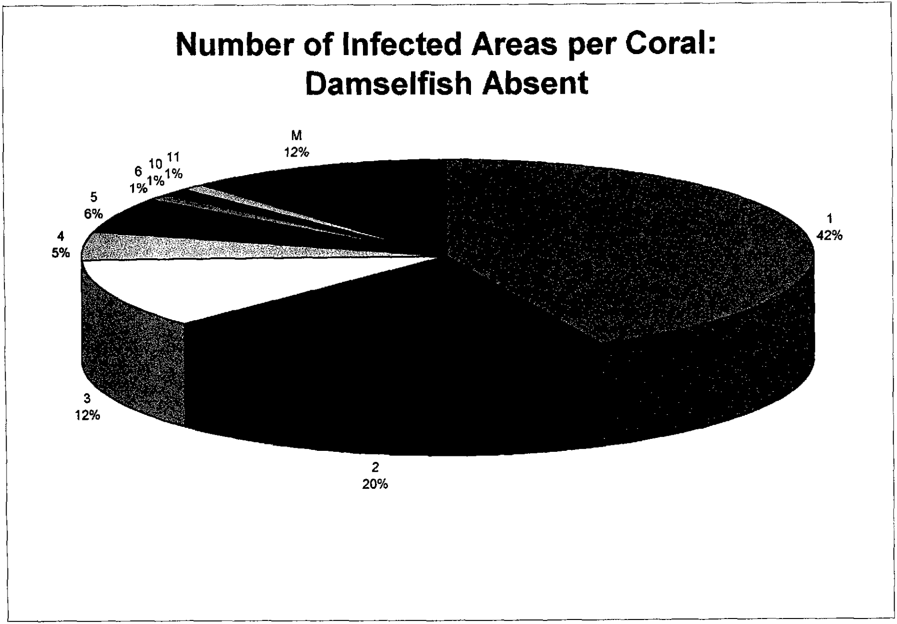

Number of Infected Areas per Coral:
Damselfish Present
M
25%
1
44%
2
10%
3
8%
4
3%
5
4%
6
2%
10
2%
12
2%

Figure 8



Number of Infected Areas per Coral: Damselfish Absent
M
12%
6
1%
10
1%
11
1%
5
6%
4
5%
1
42%
3
12%
2
20%

Figure 9

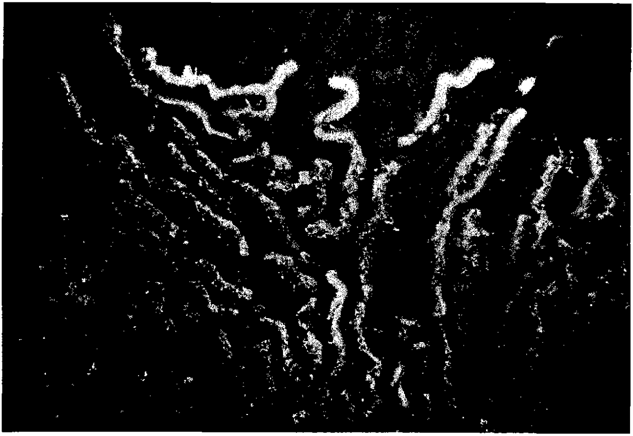
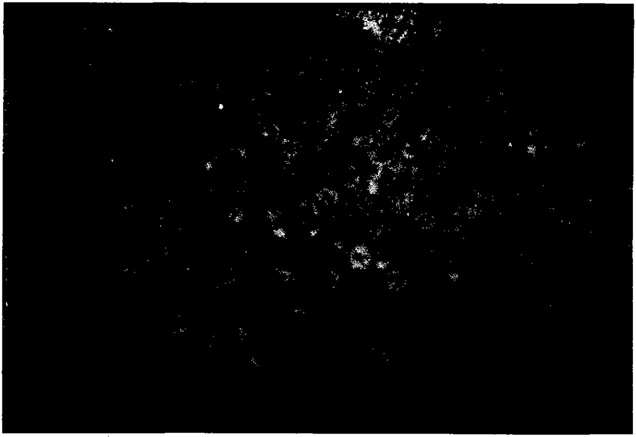
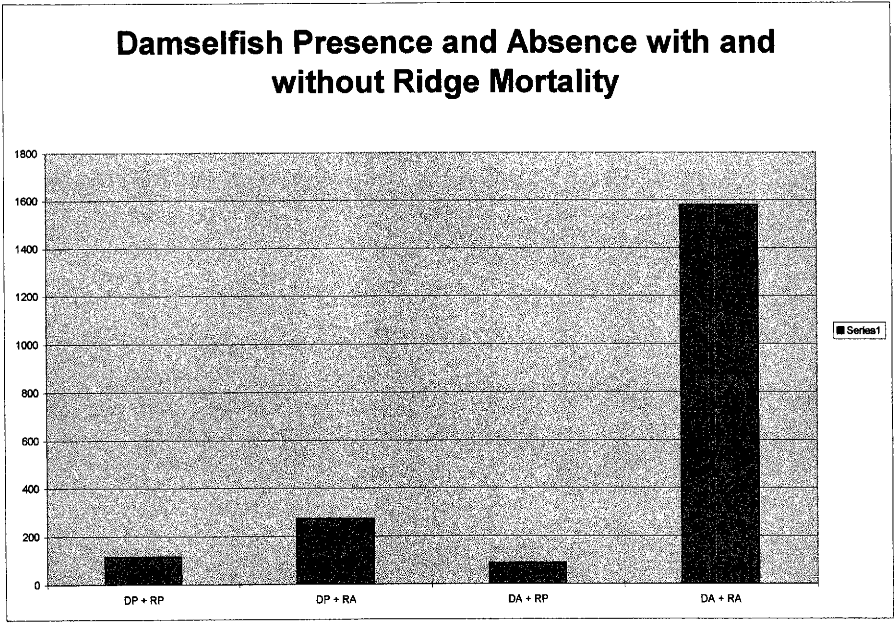
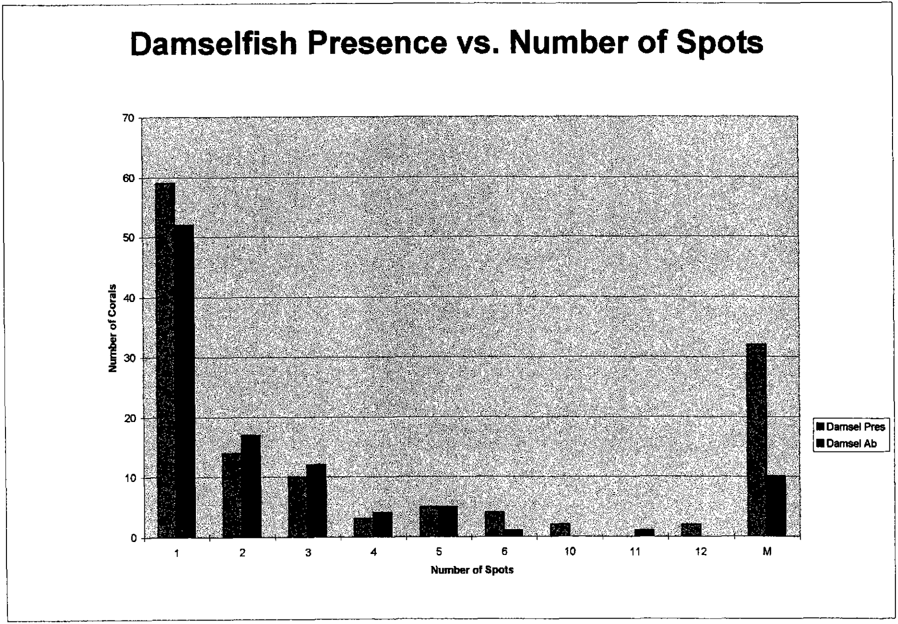


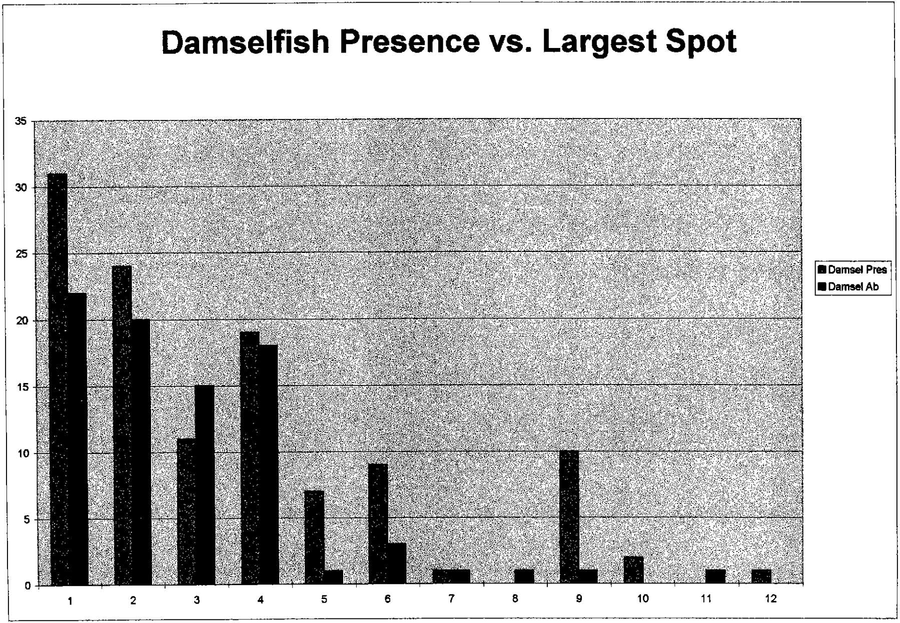
Figure 10





Damselfish Presence and Absence with and without Ridge Mortality
1800
1600
1400
1200
1000
800
600
400
200
0
DP + RP
DP + RA
DA + RP
DA + RA
Series1


Damselfish Presence vs. Number of Spots
70
60
50
40
30
20
10
0
Number of Corals
1
2
3
4
5
6
10
11
12
M
Number of Spots
Damsel Pres
Damsel Ab


Damselfish Presence vs. Largest Spot
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
Damsel Pres
Damsel Ab

Damselfish Presence vs. Total Area

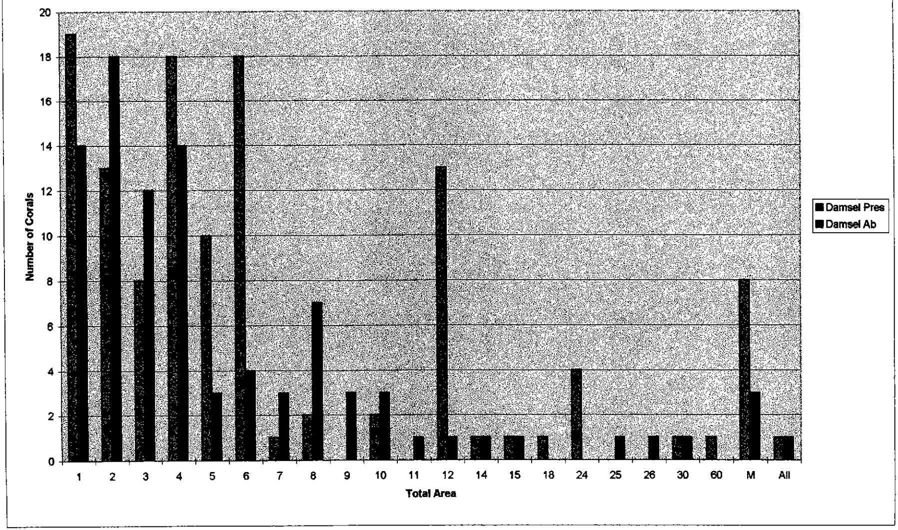
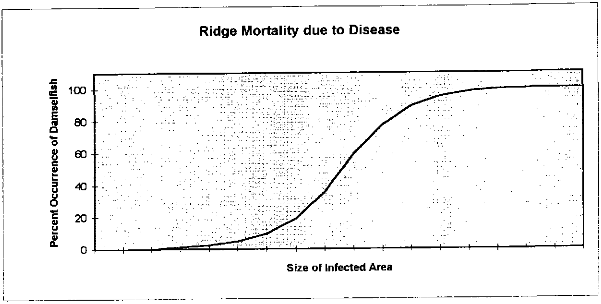
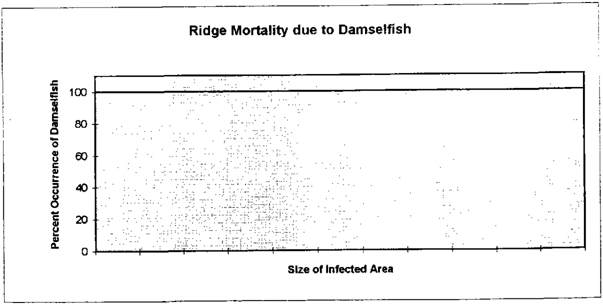


Figure 15

Graph 1



Graph 2



Appendix

Location	Date	Degree	ND W	ND W/O	DW #	Coral Size	Spot Size	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	Group	Comments
West #5	6/3/97	Random		53		1	3 All														
						1	2.5	4													
						1	4.5	3													
						1	1.5	12													
						1	1.5	12													
West#5	6/4/97	80		60		1	3	14													
						1	1.8	12													
						1	1.8	12													
West #5	6/3/97	240		56		1	1	3													
						1	2	1													
						1	4	5													
						1	2	2													
						3	1	1	1	1											
West #5	6/3/97	0		131		2	3	4	3												
						1	2	2													
						2	6	1	3												
						1	2	6													
						1	2	1.5													
						1	4	5													
						10	1	3	3	3	3	3	3	3	3	3	3				
						1	3	4													
						1	2	5													
						2	3	2	2												
West #5	6/3/97	Random		15		6	3	1	1	1	1	1	1								
						1	1	3													
West #5	6/4/97	120		81	M		1	4													
						2	0.5	2	2												
						1	1	1													
						2	4	1	3												
					M		1	1													
						1	1	2													
						6	2	1	1	1	4	4	4								
						1	2	3													
East #2	6/4/97	Random		8																	
East #2	6/4/97	270	8	58		5	3	1	1	1	1	1									
						1	2	3													
						1	5	2													
						2	3	6	6												
					M		4 6;1														
					M		2	2												B	
						3	1	1	1	1										B	
						6	1	1	1	1	1	1	1							B	
East #2	6/5/97	320	12	78		1	3	12													
						1	1.5	12													
					M		2 1,4														
						12	1	1	1	1	1	1	1	1	1	1	1	1	1		
					M		1	2													
					1,M		1.5	4	1												
						5	2	1	1	2	2	4									
East #2	6/5/97	340	70	8		1	4	1													
						2	3	1													
						1	2	6													

Location	Date	Degree	ND W	ND W/O	DW #	Coral Size	Spot Size	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	Group	Comments
					1	1.5	2														
					2	1	3	3													
					M	3	1													C	
					M	1	1													C	
					M	3	1														
					10	4	1	1	1	1	1	1	1	1	1	1				D	
					1	1	4													D	
East #2	6/5/97	Random	28	2	M	5	1;4														
					M	5	60														
					12	1.5	2	2	2	2	2	2	2	2	2	2	2	2			
					3	1.5	2														
					5	4	2	2	3	4	4										
					M	2.5	2,4														
					M	1	12														
					M	1	1,2														
West #1	7/10/97	No data	157	38	10																No size or numb
West #7	7/10/97	No data	135	72	5																No size or numb
West #5	8/24/97	10	45	11	4	2	1	1	1	0.5											
West #5	8/24/97	190	108	18	1	1.5	5														
					1	3	1														
					6	3	5	4	4	2	2	1									
					M	2	2;3														
					2	3	12	12													
					M	4	1;2														
West #5	8/24/97	Random	16	5	3	1.5	2	2	2												
					1	3	5														
West #5	8/24/97	Around sand	63	7	1	1.5	0.5														
					1	1	3														
					M	2	5														
					M	2	6														
					1	3	4														
					2	3	4	1													
					4	2	1	1	1	1											
					3	3	2	2	2												
East #7	8/25/97	No data	42	21	2	2	4	4													
					2	4	6	6													
					4	2	1	1	2	2											
					M	2	24														
East #7	8/25/97	30	53	9	2	3	4	4													
					1	1	4														
					3	1	2	2	2												
					1	3	4														
East #8	8/26/97	0	54	M	4	1;2															
					1	1	3														
					1	4	12														
					M	2	24														
East #8	8/26/97	130	68	13	3	1	2	2	2												
					1	2	6														
					1	1	6														
					1	2	4														
					1	3	6														
					1	2	4														
					3	1	2	2	2												
					1	1	4														

Location	Date	Degree	ND W	ND W/O	DW #	Coral Size	Spot Size	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	Group	Comments
East #0	8/27/87	Random	61	15	1	4	2														
					M	5	2														
					1	6	4														
					1	0.5	2														
					5	4	1	1	1	1	1										
East #2	9/9/97	210	79	9	1,M	1	4,1														
					M	1.5	2														
					M	1	0.5													E	
					3	1	2	2	2											E	
					5	2	1	1	1	1	1									E	
East #2	9/10/97	90	69	11	M	3	1														
					1,M	1.5	4;1														
					1,M	6	2;3														
					M	2	1														
					1	1.5	4														
West #2	9/11/97	71	8	1	4	12															
				1	3	5														F	
				3	0.5	1														F	
				M	0.5	1														F	
				M	1	1														F	
				1	2	6															

Location	DW/O #	Coral Size	Spot Size	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	Group	Comments
West #5	1	4.5	2														
	1	0.5	4														
	1	4.5	4														
	1	0.5	3														
	1	3	2														
	1	6	7														
West#5	1	2.25	12														
	1	4.5 All															
	1	0.6	4														
	1	4.5	4														
	1	2.2	4														
	1	1.8	4														
	1	6	11														
West #5	1	4	2														
	2	1	3	1													
	2	1		1	1												
	1	3	2														
	2	4	2	1													
	2	2	4	6													
	3	1.5	2	3	3												
	6	2	1	1	1	1	1	1									
West #5	3	3	1	1	1												
	4	2	2	2	2	2											
	2	3	3	3													
	2	4	7	7													
	1	4	1														
West #5	4	2	4	1	1	1											
West #6	10	5	2	2	2	2	2	3	3	3	3	3					
	2	2	1	3													
	2	0.5	1	1													
	2	3	1	1													
	3	1	1	1	1											A	
	4	2	2	2	2	2										A	
	M	1	1													A	
East #2	2	1	4	1													
	2	3	2	2													
	2	4	4	4													
East #2	1	2.5	4														
	3	4	1	1	3												
	1	1	1														
	2	2	4	4													
	M	2	1														
	3	1.5	1	1	1												
East #2	M	2	1														
	5	2	1	1	1	1	4										
East #2	1	2	3														
	2	2	1	1													
	2	1	1	2													

Location	DW/O #	Coral Size	Spot Size	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	Group	Comments
	1	3	1														
	5	0.5	2	2	1	2	2										
	1	1	4														
East #2	M	1.5	1														
	3	2	1	1	1												
	4	4	2	2	3	3											
	M	5 2;6															
	3	2	3	3	3												
	M	6 1;6															
	M	2.5	30														
	3	5	2	2	2												
	2	2	4	4													
	5	1.5	1	1	1	2	4										
	1	1	1.5														
	3	5	2	3	4												
West #1	11																No size or numb
West #7	12																No size or numb
West #6	1	3	2														
	5	2	1	1	1	1	1										
	1	2	3														
	1	2	2														
West #5	1 .	1	2														
	5	4	5	5	3	1	1										
	3	4	2	4	1												
West #5																	
West #5	M	1.5	6														
	1	4	4														
	1	4	2														
	1	3	3														
East #7	1	2	3														
	1	4	3														
	1	1	2														
East #7	1	5	2														
	1	2	2														
	2	1	3	1													
	M	1	1														
	1	5	2														
East #8	11	5	1	1	1	1	1	1	1	4	4	5	6				
East #8																	

Location	DW/O #	Coral Size	Spot Size	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	Group	Comments
East #6	1	4	1														
	1	6	4														
East #2																	
East #2	1,M		2 1;2														
West #2																	